Percutaneous Endoscopic Lumbar Herniectomy for High-Grade Down-Migrated L4–L5 Disc through an L5-S1 Interlaminar Approach: A Technical Note

Authors G. Choi[1], N. Prada[2], H. N. Modi[2], N. B. Vasavada[2], J.-S. Kim[1], S.-H. Lee[1]

Affiliations [1] Department of Neurosurgery, Wooridul Spine Hospital, Seoul, South Korea
[2] Department of Orthopedic Surgery, Wooridul Spine Hospital, Seoul, South Korea

Key words
- percutaneous endoscopic lumbar discectomy
- high-grade down-migrated L4–L5 disc
- L5-S1 interlaminar approach
- minimally invasive spine surgery

Abstract

Background: L4–L5 disc herniations can be treated with percutaneous endoscopic lumbar discectomy (PELD) using a transforaminal posterolateral approach. Although PELD has some distinct advantages over conventional open discectomy, inadequate decompression is a major cause of failure of the procedure, especially with high-grade migrations. The objective of this technical note is to present a new surgical approach for treating high-grade, down-migrated, L4–L5 disc herniations through an L5-S1 interlaminar endoscopic approach.

Method: This technical report presents 4 consecutive patients with high-grade, down-migrated, L4–L5 disc herniations, who were treated with PELD through an L5-S1 interlaminar approach under local anesthesia and conscious sedation. All patients were evaluated clinically using both the visual analogue scale (VAS) for back and leg pain and the Oswestry disability index (ODI) and radiologically using MR imaging postoperatively.

Results: All 4 patients experienced improvement in their preoperative symptoms and signs immediately postoperatively. The mean VAS scores for back and leg pain improved from 3.75 to 1.75 and from 8.5 to 0.75, respectively. The mean ODI score improved from 65% to 3%. Postoperative MR imaging also depicted L5 root decompression. There were no complications during the procedure.

Conclusion: This technical note presents a new technique for treating high-grade, down-migrated, L4–L5 disc herniations with PELD using an L5-S1 interlaminar approach.

Abbreviations

LDH	lumbar disc herniation
PELD	percutaneous endoscopic lumbar discectomy
PELH	percutaneous endoscopic lumbar herniectomy

Introduction

Minimally invasive spine surgery (MISS), with a focus on preserving normal spinal anatomy, is gradually replacing the traditional open lumbar discectomy that requires laminectomy or laminotomy. Percutaneous endoscopic lumbar discectomy (PELD), a minimally invasive spine surgical procedure developed and popularized by pioneers such as Hijikata, Kambin, Yeung and others, has become a versatile minimally invasive spine surgical procedure for treating lumbar disc herniations [1–4]. Originally, it was devised to treat only contained lumbar disc herniations (LDH). With growing experiences and advances in technology, the spectrum of PELD is gradually expanding day by day with some of the contraindications of the past now becoming the indications of the present [2, 5–14]. Modern endoscopic surgeons are able to deal with a non-contained extruded disc, a migrated disc, or even a sequestrated disc through a transforaminal posterolateral endoscopic approach, as described by Kambin et al. [2], using local anesthesia. Patients with extraforaminal LDH, LDH with foraminal narrowing, a difficult L5-S1 level, or a high iliac crest can now be treated with PELD [8, 14–16].

Recently, Choi et al. [15] reported successful results after treating patients with a difficult L5-S1 level (due to a high iliac crest and narrow transforaminal area) and intracanalicular disc herniations with L5-S1 interlaminar PELD, using a rigid working channel endoscope. At our insti-

Bibliography
DOI http://dx.doi.org/10.1055/s-0030-1254145
Minim Invas Neurosurg 2010; 53: 147–152

ISSN 0946-7211

Correspondence
Dr. H. N. Modi
Department of Orthopedic Surgery
Wooridul Spine Hospital
47-4 Chungdam-dong
Gangnam-gu
Seoul 135-100
Korea
Tel.: +82/2/513 8151
Fax: +82/2/513 8146
modispine@yahoo.co.in

tute, we prefer to use the term percutaneous endoscopic lumbar herniectomy (PELH) instead of PELD, because we remove only the herniated mass without the central nucleus material. In spite of this advantage, PELH has some limitations; migrated disc herniations are still considered technically demanding to treat. The failure of PELH is largely attributable to inadequate decompression due to the presence of remnant fragments/fragments, which are more common in patients with high-grade disc herniations as described by Lee et al. [17]. They concluded that in a patient with high-grade disc migration, open lumbar microdiscectomy instead of PELD is often indicated. They also suggested the lower border of the pedicle as the limit, as migration beyond this limit usually is associated with a high failure rate.

In this technical report, we present a new approach for treating high-grade, down-migrated, L4–L5 disc herniations with a percutaneous endoscopic approach in which a rigid working channel endoscope is passed through the L5-S1 interlaminar space. Our aim is to present this technique as an option for treating the L4–L5 down-migrated disc using PELD and to report clinical as well as radiological results after a minimum follow-up period of 2 years.

Patients and Methods

Four consecutive patients (3 males and 1 female) with high-grade, down-migrated, L4–L5 disc herniations were treated with L5-S1 interlaminar PELH between March and September, 2007. The selection criteria included: 1) L5 radiculopathy that was non-responsive to brief conservative treatment (we could not follow a longer conservative treatment plan due to the severity of the pain); 2) MR imaging suggestive of a high-grade, down-migrated L4-5 disc (the disc was considered high-grade migrated if the extent of the migration was greater than the measured height of the posterior marginal disc space on the T_2-weighted sagittal MR, as described by Lee et al. [17]); and 3) The existence of a wide interlaminar window at the L5-S1 level (to lodge the working cannula of the endoscope into the interlaminar space, a 7-mm wide superior-inferior interlaminar space on the AP view was considered the minimum allowable width). The patients who showed signs of cauda equina syndrome, significant bony stenosis, and/or segmental instability were excluded from this procedure.

The preoperative and postoperative evaluations included: 1) a thorough clinical examination (straight leg raising [SLR], motor and sensory evaluation), 2) assessment of leg and back pain with the visual analogue scale (VAS), 3) assessment of functional disability with the Oswestry disability index (ODI), 4) charting, and 5) radiological evaluation (lumbo-sacral spine AP/lateral/dynamic view radiographs, MRI, and CT). Postoperatively, all patients were subjected only to MR imaging to confirm the adequacy of decompression or to locate remnants of fragments.

Surgical technique

In general, the surgical technique is not very different from that described in a previously published article on the L5-S1 interlaminar approach [15]; however, this is considered as an extended use of this technique due to the advantageous pathoanatomic features of a high-grade, down-migrated L4–L5 disc that make the surgery possible.

After administration of prophylactic antibiotics, the patient was placed in the lateral decubitus position with the affected side facing upwards. Conscious sedation was induced with midazolam (Roche Korea, Seoul, Korea) (3 µg intramuscularly) and fentanyl (Hana Pharm, Seoul, Korea) (50 µg intravenously), because continuous feedback from the patient is very important for avoiding insult to the neural tissues. To reach the safest area at the shoulder of the S1 nerve root, the skin entry point was decided preoperatively based on the axial MR image. The skin entry point and the tract were infiltrated with 1 % lidocaine. The skin entry point was generally slightly caudal to the L5-S1 disc space. From the skin entry point, one 18-gauge needle was targeted at the most lateral area of the interlaminar space, as visualized with the fluoroscope on the AP view. After confirming the needle location with an epidurogram, an epidural block was given with about 10 mL of 1 % lidocaine after aspiration to avoid vascular infusion. The silhouette of neural structures on the epidurogram helps to identify the safe zone for accurate cannula insertion. Through a 0.5- to 0.7-mm skin incision, the guidewire was then inserted through the needle followed by sequential dilatation of the tract (the ligamentum flavum is not excised, it is just split through the sequential dilatation). Dilation of the tract up to 6 mm was required to accommodate the cannula through which the endoscope (YESS; Richard Wolf, GmbH, Knittlingen, Germany; a 20 degree scope with a 2.7-mm working channel) was inserted with a continuous inflow of normal saline with antibiotics. To reach the down-migrated L4–L5 fragment, the angle of the working channel was maintained slightly more caudocephalic (targeting the L5 pedicle on the lateral fluoroscopic image) than the angle used in the standard interlaminar approach for L5-S1 disc herniations. From the shoulder area of the S1 nerve root, it was possible to reach the down-migrated fragment, which was mostly found in the axilla of the L5 nerve root (**Fig. 1**). The round-ended cannula protected the surrounding neural structures. After identification of the herniated mass, herniectomy was performed using various grasping forceps, the side-firing holmium-YAG laser (Lumenis, Inc., New York, NY), and the Ellman flexible tip radiofrequency (RF) probe (Trigger-Flex, Ellman International Inc., Oceanside, NY) attached to a high RF generator (Surgitron, Ellman International Inc.), under continuous irrigation with antibiotic-impregnated normal saline. The flexible tip of the Ellman RF probe can be used for hemostasis and also for tissue dissection. The L5 exiting root was visualized along its course to confirm adequate decompression (**Fig. 2**). After removal of the scope, a single stitch was used to close the skin incision and a sterile dressing was applied.

Results

Preoperatively, all of the patients had severe leg and back pain and were not able to walk or stand for more than 5 min. Two patients had great toe weakness (Grade III). One of our patients had a disc that – along with a down-migrated fragment – caused significant paramedian compression of the L5 root at the L4–L5 disc level (**Fig. 3**, **Fig. 4**). This patient refused open surgery, hence, was subjected to L4–L5 transforaminal PELH for the paramedian decompression and L5-S1 interlaminar PELH for removal of the down-migrated disc fragment.

Postoperatively, all 4 patients were mobilized during the evening of the same day and were subjected to a physiotherapy protocol. The immediate postoperative evaluation included a physical examination with performance of the straight leg raising test,

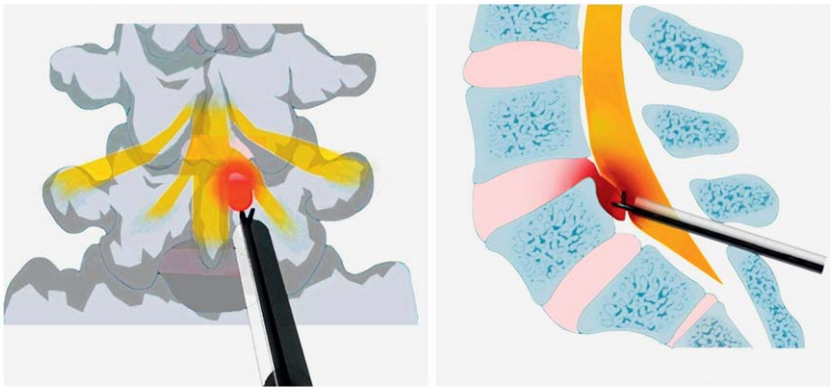

Fig. 1 An illustrative sketch of the treatment of a down-migrated L4–L5 disc herniation through the L5-S1 interlaminar approach using the percutaneous endoscopic lumbar herniectomy technique.

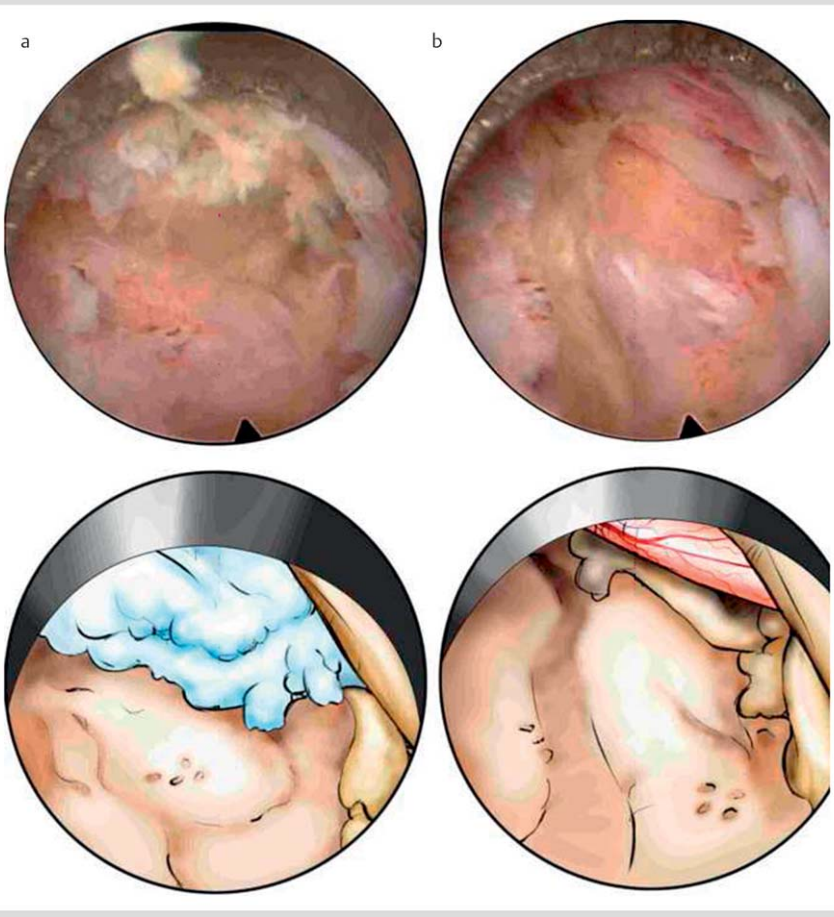

Fig. 2 **a** Intraoperative endoscopic view showing a blue-stained migrated disc fragment. **b** Intraoperative endoscopic view after removal of the herniated and migrated fragment. It shows a decompressed exiting L5 root (12 o'clock to 2 o'clock position).

neurological examination, and MR imaging. All 4 patients were relieved of their preoperative subjective and objective symptoms and signs, respectively, without any neurological deterioration. VAS and ODI scores showed significant improvements between the preoperative and postoperative assessments (**Table 1**). The mean VAS score for back pain improved from 3.75 to 1.75, while that for leg pain improved from 8.5 to 0.75. The mean ODI score improved from 65% to 3%. Postoperative MR findings also corroborated the clinical findings that documented the decompression of the L5 nerve root. There were no complications during the surgical procedure, and the mean operative time was 106 min. All patients were discharged the next day with oral antibiotics. All patients returned to work within 2 weeks of the surgery. Recent follow-up after a minimum 2-year period revealed that none of the patients had experienced recurrence or segmental instability of the affected or adjacent segments.

Discussion

In 1975, Hijikata was the first to perform a percutaneous discectomy [1]; however, posterolateral endoscopic transforaminal surgery to optimize the route to the spinal canal under continuous visualization has been performed since the late 1990s [18]. Since then, there have been many modifications reported for the treatment of various types of disc herniations with percutaneous endoscopy. Some of the contraindications of the past are now the indications of the present [8,13–16]. The universal experience with percutaneous endoscopy offers favorable out-

Fig. 3 Preoperative T_2-weighted MR scans obtained in the 4 patients.

Fig. 4 Postoperative MR scans obtained in the 4 patients.

comes for soft disc herniations [3,4,17–20]. Moreover, because it is a procedure performed under local anesthesia, the postoperative rehabilitation is very rapid and smooth. Microdiscectomy currently constitutes the standard treatment for herniated lumbar discs. Thome et al. compared the early outcomes and rates of recurrence of sequestrectomy and microscopic discectomy in 84 patients with extruded or migrated lumbar discs. Sequestrectomy does not seem to entail a higher rate of early recurrences compared with microdiscectomy. Analysis of early outcomes demonstrated a trend toward superior results when sequestrectomy was performed, presenting sequestrectomy as an advantageous alternative to standard microdiscectomy [21]. Similarly, we have started preferring the term PELH to PELD, as the surgeons at our institute remove only the herniated mass, never the intradiscal nucleus material. The present new technique performed through an L5-S1 interlaminar approach is a simple herniectomy for a down-migrated L4-5 disc, and the results are comparable to those obtained with microdiscectomy.

L4–L5 disc herniations are conveniently accessed through the standard transforaminal approach except in patients with a very high iliac crest. However, difficulty in achieving adequate resection of herniated discs within the spinal canal cannot always be excluded [17]. The osseous perimeter of the foramen, the pedicle, and the exiting nerve can limit the working mobility and excision of dislocated or migrated herniated material. According to Lee et al. [17], patients with high-grade migrated discs have less favorable outcomes than those with near-migrated or non-migrated discs treated with conventional transforaminal PELD. In this series, all of the patients had high-grade, down-migrated L4-5 discs, as per described by Lee et al. [17]. There is no consensus as to the degree of migration that can be removed using current endoscopic instruments through the standard approach. In the literature, the accessible boundary is accepted as the mid-pedicle level of the lower body in downward migration [17]. Hence, in the present patients, it was not possible to treat them with the conventional transforaminal approach. To reach the migrated fragment, the interlaminar approach may require removing a much larger portion of the L5 upper lamina than the portion removed during routine operations for non-migrated disc herniations, even with an open procedure. Choi et al. [22] reported excellent outcomes after treating 59 patients with high-migrated intracanal disc herniations with the foraminoplastic technique. However, in using this technique, especially for a down-migrated disc, removal of the undersurface of the articular process using a drill is necessary, which increases the width of the foramen and exposes the anterior epidural space. However, with our technique, there is not much need to remove bony structures, thus, avoiding possible instability. Additionally, it can be done under local anesthesia, which is the most important advantage of our technique. Moreover, our technique is also easily possible to perform in a patient with a high iliac crest, as a high iliac crest does not interfere with this interlaminar approach.

The various, atypical, anatomic features of the L5-S1 interlaminar space, as described by Choi et al. [15], make the described approach possible. There is less laminar overhang of the L5 vertebra, and the L5-S1 interlaminar space is the largest space compared to those at other lumbar levels. The interesting peculiarity of the L5 lamina is evident in the coronal plane, where it slopes backwards and downwards. This helped us to angle our working channel more caudocranially to reach the down-migrated L4–L5 disc fragment. We believe that a prerequisite for this approach is

Table 1 Pre- and postoperative VAS score for leg pain and back pain and Oswestry disability index (ODI).

	Patient 1	Patient 2	Patient 3	Patient 4
preoperative VAS (Leg pain)	8	8	9	9
postoperative VAS (Leg pain)	1	1	1	0
preoperative VAS (Back pain)	4	5	3	3
postoperative VAS (Back pain)	2	0	3	2
preoperative ODI (%)	50	60	72	78
postoperative ODI (%)	2	6	2	2

a sufficiently wide L5-S1 interlaminar space (as mentioned earlier, the minimum is a 7-mm space on the AP view). Caudocranial angulation of the cannula can be easily accommodated by the oblique nature of the L5 laminae. Patients with a large interlaminar space can be managed through this approach without the need for a separate L4–L5 transforaminal approach for paramedian decompression. In patients with a relatively small interlaminar window, the transforaminal route at the index level is necessary for paramedian decompression. In our experience, a high-grade, down-migrated L4–L5 disc is generally located in the axilla of the L5 nerve root. Therefore, an approach through the shoulder region of the S1 nerve root at the L5-S1 interspace can lead us to the herniated mass located at the axilla of the L5 nerve root. The L5 nerve root is generally abated with the L5 pedicle by compressing the axillary migrated disc fragment, making the angle of the L5 root with the thecal sac wider and safe for endoscopic maneuvering. However, the characteristics of the high-grade down-migrated disc make the L4–L5 interlaminar approach, as described by Reutten et al. [6], very difficult. This approach requires the shoulder area of the L5 nerve root, which is compromised due to the displaced L5 nerve root; this makes the L5 nerve root more vulnerable to injury if this approach is attempted. In contrast to this, the L5 axillary mass, which has reached up to the L5 interior endplate, also displaces the S1 nerve root that has already emerged from the thecal sac [23,24] more towards the thecal sac and enlarges the safety zone at the shoulder region of the S1 nerve root. Furthermore, gradual dilatation of the S1 shoulder area protects the exiting L5 and traversing S1 nerve roots. Due to the wide interlaminar space and expanded safety zone, we could reach almost beyond the midpedicle level of the L5 vertebra through the L5-S1 interlaminar space.

The important characteristic of this approach besides the advantages of a percutaneous procedure [15] is the dilatation of the natural barrier of the ligamentum flavum to reach the epidural space; on removal of the instruments, the ligamentum flavum falls back to seal the entry due to its inherent elasticity. This barrier prevents, as described in the literature [25,26], postoperative peridural and perineural fibrosis. Kast et al. recently reported that the competence of the fibrous ring significantly influenced the success of a simple sequestrectomy compared with conventional microdiscectomy in their patients. There was a comparably low number of recurrences in both groups, which was probably due to the consequent selection of patients for sequestrectomy according to well-defined criteria [27]. We also emphasize that for the L4–L5 down-migrated disc, this new technique should be restricted to only those patients who require only sequestrectomy. Recently, Papavero et al. reported surgical success using a microsurgical translaminar approach in preserving the integrity of almost all structures of the spine in 104 patients with upward-migrated disc lesions compressing the root above the level [28]. Similar to Papavero et al., our technique specifically demonstrated successful results in the treatment of down-migrated L4-5 discs, while preserving the integrity of all structures of the spine. Indications for our technique are thus different from those for their technique, but the techniques are based on the same principle and offer similar clinical benefits.

The disadvantages of this approach, similar to those associated with conventional PELD, are the steeper learning curve, expensive inventories, radiation exposure, and theoretical possibility of damage to neural structures [15]. In addition, the prerequisite for this procedure is a wide interlaminar L5-S1 space. When using the interlaminar approach, resection of the intradiscal nucleus material is frequently constrained because of the divergent level between the interlaminar window and the intervertebral space. Reutten et al. [29] reported a 6% recurrence rate when the endoscopic interlaminar approach was used for selective fragmentectomy; however, the recurrence rate was lower than that for conventional selective fragmentectomy for L5-S1 disc herniation [30–33]. Our first 4 patients did not experience any recurrence during the minimum 2-year follow-up period; however, we need a longer follow-up period with a larger patient database to determine the recurrence rate for down-migrated L4–L5 discs treated through the L5-S1 interlaminar approach. This approach makes treating the complicated, high-grade, down-migrated L4–L5 disc simpler and safer and also provides satisfactory results. Systematic and detailed preoperative planning, orientation with the lumbar canal anatomy, and experience with the procedure can surely avoid unwanted complications.

Conclusion

Percutaneous endoscopic L5-S1 interlaminar discectomy with a rigid working channel endoscope for the treatment of high-grade, down-migrated, L4–L5 disc herniations can be a safe, effective, and minimally invasive procedure in patients with a wide L5-S1 interlaminar space.

Conflict of Interest: All authors stated that there is no conflict of interest regarding the publication of this manuscript.

References

1 *Hijikata S, Yamagishi M, Nakamata T et al.* Percutaneous nucleotomy: a new treatment method for lumbar disc herniation. J Toden Hosp 1975; 5: 5–13
2 *Kambin P, Gellman H.* Percutaneous lateral discectomy of the lumbar spine. A preliminary report. Clin Orthop 1983; 174: 150–167
3 *Kambin P, O'bren E, Zhou L.* Arthroscopic microdiscectomy and selective fragmentectomy. Clin Orthop 1998; 347: 150–167
4 *Yeung A, Tsou P.* Posterolateral endoscopic excision for lumbar disc herniation: surgical techinique, outcome, and complication in 307 consecutive cases. Spine 2002; 27: 722–731
5 *Schubert M, Hoogland T.* Endoscopic transforaminal nucleotomy with foraminoplasty for lumbar disc herniation. Opera Ortho Traumatology 2005; 17: 641–661

6 *Ruetten S*. The full endoscopic interlaminar approach for lumbar disc herniations. In: *Mayer HM* (ed.): Minimally Invasive Spine Surgery. Berlin: Springer; 2005; 346–355
7 *Ruetten S*, *Komp M*, *Godolias G*. Full-endoscopic interlaminar operation of lumbar disc herniations using new endoscopes and instruments. Orthop Praxis 2005; 10: 527–532
8 *Ruetten S*, *Komp M*, *Godolias G*. An extreme lateral access for the surgery of lumbar disc herniations inside the spinal canal using the full-lendoscopic uniportal transforaminal approach. Techinque and prospective results of 463 patients. Spine 2005; 30: 2570–2578
9 *Kambin P*, *Casey K*, *O'Brien E et al*. Transforaminal arthroscopic decompression of lateral recess stenosis. J Neurosug 1996; 84: 462–467
10 *Jang J*, *An S*, *Shi L*. Transforaminal percutaneous endoscopic discectomy in the treatment of foraminal and extraforaminal lumbar disc herniations. J Spinal Disord Tech 2006; 19: 338–343
11 *Yeung A*, *Yeung C*. Advances in endoscopic disc and spine surgery: foraminal approach. Surg Technol Int 2003; 11: 255–263
12 *Tsou P*, *Yeung C*, *Yeung A*. Posterolateral transforaminal selective endoscopic discectomy and thermal annuloplasty for chronic lumbar discogenic pain: a minimal access visualized intradiscal surgical procedure. Spine J 2004; 4: 564–573
13 *Tsou P*, *Yeung A*. Transforaminal endoscopic decompression for radiculopathy secondary to intracanal noncontained lumbar disc herniations: outcome and technique. Spine J 2002; 2: 41–48
14 *Choi G*, *Lee S*, *Bhanot A et al*. Percutaneous endoscopic discectomy for extraforaminal lumbar disc herniations: Extraforaminal targeted fragmentectomy techenique using working channel endoscope. Spine 2007; 32: 93–99
15 *Choi G*, *Lee S*, *Raiturkar P et al*. Percutaneous endoscopic interlaminar discectomy for intracanalicular disc herniations at L5-S1 using a rigid working channel endoscope. Neurosurgery 2006; 58: 59–68
16 *Choi G*, *Kim JS*, *Lokhande P et al*. Percutaneous endoscopic lumbar discectomy by transiliac approach: a case report. Spine (Phila Pa 1976) 2009; 34: E443–E446
17 *Lee SH*, *Kang BU*, *Ahn Y et al*. Operative failure of percutaneous endoscopic lumbar discectomy: A radiological analysis of 55 cases. Spine 2006; 31: 285–290
18 *Ahn Y*, *Lee S*, *Park H et al*. Posterolateral percutaneous endoscopic lumbar foraminotomy for L5-S1 foraminal or lateral exit zone stenosis. Technical note. J Neurosurg 2003; 99: 320–323
19 *Hijikata S*, *Yamagishi M*, *Nakamata T et al*. Percutaneous nucleotomy: a new treatment method for lumbar disc herniation. J Toden Hosp 1975; 5: 5–13
20 *Hermantin F*, *Peter T*, *Quartararo L et al*. A prospective, randomized study comparing the result of open discectomy with those of video assisted arthroscopic microdiscectomy. J Bone Joint Surg [Am] 1999; 81: 958–965
21 *Thome C*, *Barth M*, *Scharf J et al*. Outcome after lumbar sequestrectomy compared with microdiscectomy: a prospective randomized study. J Neurosurg Spine 2005; 2: 271–278
22 *Choi G*, *Lee SH*, *Lokhande P et al*. Percutaneous endoscopic approach for highly migrated intracanal disc herniations by foraminoplastic technique using rigid working channel endoscope. Spine (Phila Pa 1976) 2008; 33: E508–E515
23 *Cohen M*, *Wall E*, *Brown R et al*. Acromed Award in basic science. Cauda equine anatomy II: extrathecal nerve roots and dorsal root ganglia. Spine 1990; 15: 1248–1251
24 *Hasegawa T*, *Mikawa Y*, *Watanabe R et al*. Morphometric analysis of the lumbosacral nerve roots and dorsal ganglia by magnetic resonance imaging. Spine 1996; 21: 1005–1009
25 *Askar Z*, *Wardlaw D*, *Choudhary S et al*. A ligamentum flavum preserving approach to the lumbar spinal canal. Spine 2003; 28: 385–390
26 *Sonog J*, *Park Y*. Ligament-sparing lumbar microdiscectomy: Technical note. Surg Neurol 2000; 53: 592–597
27 *Kast E*, *Oberle J*, *Richter HP et al*. Success of simple sequestrectomy in lumbar spine surgery depends on the competence of the fibrous ring: a prospective controlled study of 168 patients. Spine (Phila Pa 1976) 2008; 33: 1567–1571
28 *Papavero L*, *Langer N*, *Fritzsche E et al*. The translaminar approach to lumbar disc herniations impinging the exiting root. Neurosurgery 2008; 62: 173–177; discussion 177–178
29 *Ruetten S*, *Komp M*, *Merk H et al*. Use of newly developed instruments and endoscopes: full-endoscopic resection of lumbar disc herniations via the interlaminar and lateral transforaminal approach. J Neurosurg Spine 2007; 6: 521–530
30 *Boyer P*, *Srour R*, *Buchheit F et al*. Lumbar disc hernia. Excision of hernia with or without complementary discectomy? Neurochirurgie (1994 Fr); 40: 259–262
31 *Hirabayashi S*, *Kumano K*, *Ogawa Y et al*. Microdiscectomy and second operation for lumbar disc herniation. Spine 1993; 18: 2206–2211
32 *Stambough J*. Lumbar disc herniation: an analysis of 175 surgically treated cases. J Spinal Disord Tech 1997; 10: 488–492
33 *Wenger M*, *Mariani L*, *Kalbarczyk A et al*. Long-term outcome of 104 patients after lumbar sequestrectomy according to Williams. Neurosurgery 2001; 49: 329–334